Life-Saving Treatment by Fluid Resuscitation and a Thoracotomy in a Case of Deep Pulmonary Laceration

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Case **A 41-year-old man survived deep pulmonary and hepatic lacerations by treatment with fluid resuscitation, blood transfusion, thoracotomy, and transcatheter hepatic artery embolization. The patient was transferred to our hospital 46 minutes after his motorbike struck a station wagon from behind. Hemorrhagic shock with systolic blood pressure of 68 mmHg was observed. He showed nonresponse to 20-minute intravenous infusion of 1,500 mL of lactated Ringer's solution. The initial plain chest radiograph showed mediastinal deviation to the left, radio-opacity of the right lower lobe, and decreased radiolucency of the right thorax. Rapid drainage of 800 mL of blood through a right chest tube led to a diagnosis of a deep pulmonary laceration of the right lower lobe. Abdominal computed tomography revealed another deep laceration affecting 40% of the liver. A right lower lobectomy of the lung was performed at 169 minutes after arrival. After the thoracotomy, transcatheter arterial embolization of the right hepatic artery was performed. The patient was discharged on hospital day 57.**

Conclusion **Prompt diagnosis and appropriate treatment are necessary to save patients with multiple, severe blunt injuries. Advanced Trauma Life Support (ATLS) guidelines should be adhered to for appropriate early treatment of patients with severe trauma.**

Key words: blunt trauma, deep pulmonary laceration, fluid resuscitation, Advanced Trauma Life Support (ATLS), indication of emergency thoracotomy

INTRODUCTION

A deep pulmonary or hepatic laceration due to blunt trauma is a critical condition; it can be fatal even in uncomplicated cases. The prognosis is quite poor if a deep hepatic laceration is accompanied by a pulmonary laceration. We recently treated a patient with deep lacerations of both the lung and liver, caused by blunt trauma, who later developed hemorrhagic shock due to massive thoracic and intraperitoneal bleeding. The life of this patient was saved by intravenous (IV) solution therapy and a blood transfusion followed by an emergency thoracotomy and percutaneous hepatic artery embolization.

CASE

The patient was a 41-year-old man. In March 2004, at 15:20, his motorbike hit the back of a station wagon that was stopped on a highway. At 15:43, a rescue crew arrived at the scene. At 16:06, he was transported to the Advanced Critical Care Center of our hospital. Upon arrival, the patient's vital signs were as follows: respiration rate, 28/min; heart rate, 100/min; and systolic blood pressure, 68 mmHg. He had a Glasgow Coma Scale of E3V2M4. His breath sounds on the right side were very weak, thus suggesting tension pneumothorax on that side. Drainage of the right thoracic cavity produced air leakage and rapid and massive bloody discharge. The thoracic drain was clamped when the blood output volume reached 800 mL. A sonographic assessment for trauma revealed bleeding within the right thoracic and peritoneal cavities and hepatic injury, indicated hemorrhagic shock. The pulse rate, systolic blood pressure, the volume of IV solution administered, and the volume of blood transfused over the first 5 hours after arrival are shown in Figure 1. During the first 20 minutes after arrival, 1,500 mL of lactated Ringer's solution was infused. The patient's systolic blood pressure rose to 100 mmHg, but it began to decrease soon thereafter. As a result, the patient was not responsive to the initial treatment.

The first plain chest radiograph obtained in the supine position 5 minutes after the patient's arrival is shown in Figure 2. Although air and 800 mL of blood had been eliminated by that time with a right thoracic drain, the right margin of the mediastinal shadow was located at the right end of the thoracic vertebrae, thus indicating a shift of the mediastinum to the left. Furthermore, an infiltrative shadow was visible in the lower field of the right lung, and radiolucency was low in the right thoracic cavity, thus suggesting moderate amounts of blood remaining within the right thoracic cavity. In addition, multiple rib fractures were noted at the level of Th1-9 on the right side. Based on the blood output via the thoracic drain and features of the plain chest radiograph, a deep pulmonary laceration of the right lower lobe (ICD-9: 861.31), accompanied by hemothorax and hemorrhagic shock, was diagnosed. A surgeon specializing in thoracic trauma was called in to treat this case.

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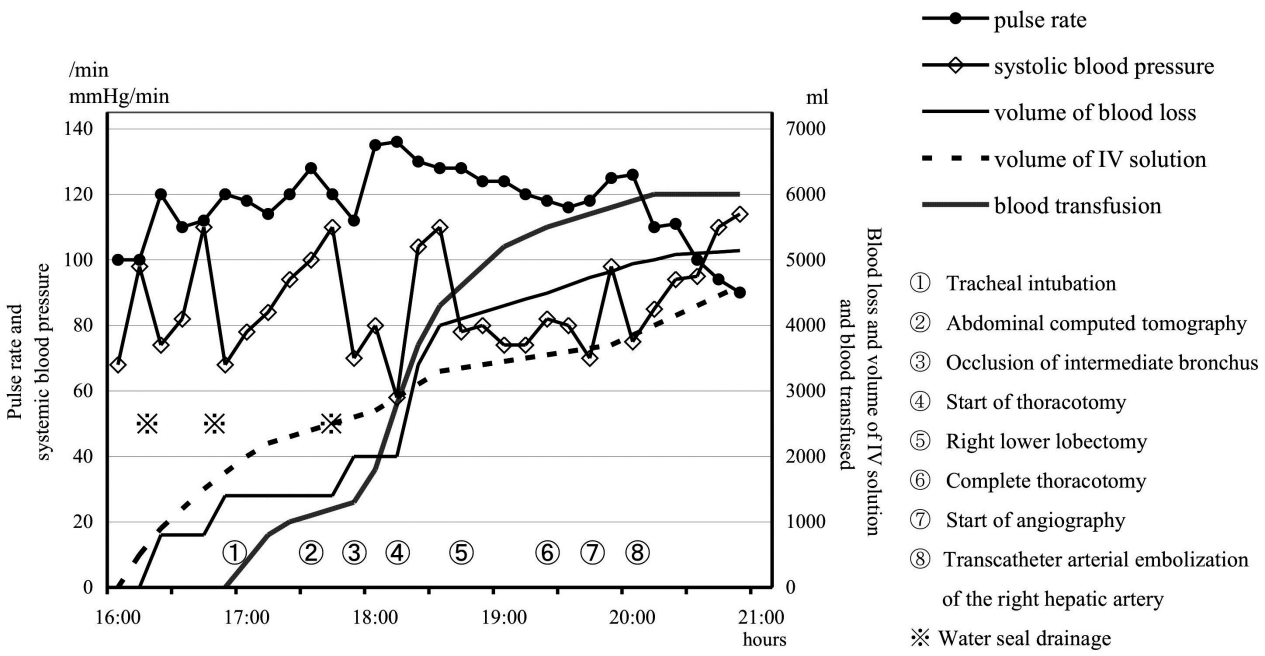

Fig. 1 The time course of changes in the pulse rate, systolic blood pressure, blood loss, and volumes of intravenous (IV) solution and blood transfused.

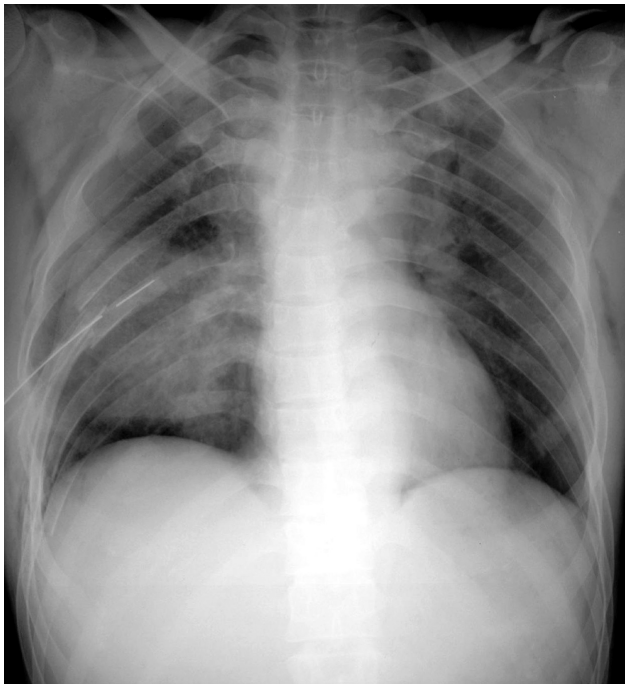

Fig. 2 Initial plain chest radiograph obtained with the patient in the supine position immediately after insertion of a right chest tube and discharge of air and blood loss of 800 mL through the chest tube. The mediastinum deviates toward the left, suggesting tension pneumothorax; the right lower lobe shows radio-opacity without lung collapse; and the right thoracic cavity shows decreased radiolucency. These findings led to a diagnosis of right hemothorax due to deep pulmonary laceration of the right lower lobe. Multiple rib fractures, affecting the right first to ninth ribs, are also seen.

A blood gas analysis, which was carried out while the patient was receiving oxygen through a mask (10 L/min) 5 minutes after arrival at the center, yielded the following: pH, 7.206; $PaCO_2$, 35.1 mmHg; PaO_2, 86.3 mmHg; HCO_3^-, −14.3 mmHg; and lactate, 81 mg/dL. The white blood cell count was 8,400/mm^3, platelet count was 19.2/mm^3, and hemoglobin was 12.8 mg/dL. Biochemical tests yielded the following: creatine, 1.4 mg/dL; BUN, 17 mg/dL; amylase, 1,055 mg/dL; GOT, 603 IU/L; GPT, 806 IU/L; CPK, 509 IU/L; and total bilirubin, 0.5 mg/dL.

Because shock persisted, tracheal intubation was performed at 17:00 to establish positive pressure mechanical ventilation. The transfusion of a concentrated erythrocyte preparation maintained the patient's blood pressure at 90 mmHg. To evaluate the patient's condition and determine the most appropriate treatment for hepatic injury, abdominal dynamic contrast-enhanced computed tomography (CT) was performed. A low density area (10 × 10 cm) was noted in the posterior segment of the right portion of the liver, and the contrast level of the center of this area was identical to that of the abdominal aorta, thus suggesting arterial bleeding (Fig. 3). CT images of the area caudal to this site revealed signs of hematoma in Morrison's pouch and bilateral paracolonic fissures. A deep hepatic laceration was diagnosed based on the presence of 40% liver injury and intraperitoneal bleeding (ICD-9: 864.04). The thorax was given an abbreviated injury scale (AIS)$^{-90}$ score of 5, and the abdomen was given an AIS score of 4; the injury severity score (ISS)$^{-90}$ was 41. We thus decided to perform an emergency thoracotomy and transcatheter arterial embolization of the hepatic laceration.

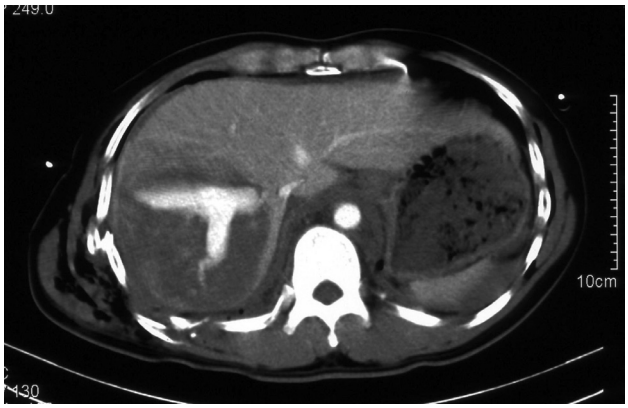

Fig. 3 An abdominal dynamic contrast-enhanced computed tomography scan obtained 70 minutes after the patient's arrival at the hospital. A low-density area, 10 × 10 cm, is visible behind the liver. In the center of this low-density area is an area comparable in density to that of the abdominal aorta, representing extravascular leakage and suggesting arterial bleeding. The presence of a hematoma around the descending aorta suggests aortic injury or injury to the intercostal artery.

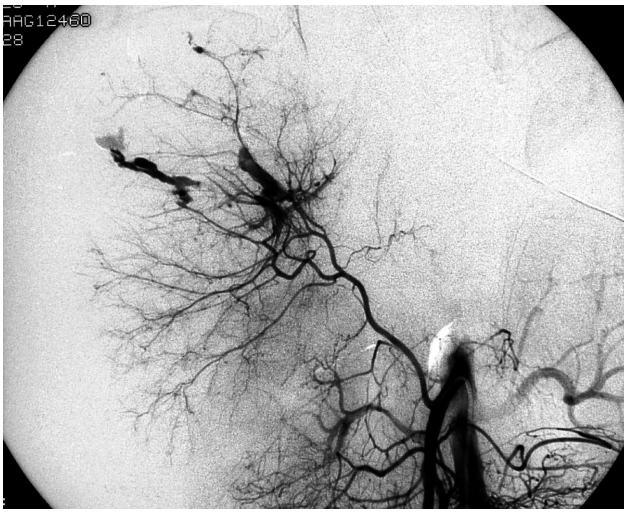

Fig. 4 Arterial phase of superior mesenteric arteriography. The leakage of contrast material is visible at multiple points in a retrohepatic branch at the periphery of the replaced right hepatic artery bifurcating from the superior mesenteric artery.

To prevent tension pneumothorax, the thoracic drainage was changed to water seal drainage at two time points (16:50 and 17:40). Although the amount of discharged air was minimal, a 600-mL volume of blood was eliminated each time. Because the systolic blood pressure suddenly dropped to 66 mmHg, the thoracic drain was clamped again, and additional blood was transfused. Bleeding from the right lower bronchial trunk was then observed. Tracheal intubation was performed again at 17:50 with a Univent® (Fuji Systems Corporation, Tokyo, Japan) tube [1]. The intermediate bronchus was occluded with the blocker attached to the tube to prevent the patient from being suffocated by his own blood.

While rapid IV solution therapy and blood transfusion were being performed, the thorax was opened at the 6th intercostal space at 18:15 with the patient on his left side. The right thoracic cavity was found to contain large amounts of blood. Immediately after the thorax was opened, the systolic blood pressure decreased to 58 mmHg. The surgeon manually blocked the right pulmonary hilus and controlled the intrathoracic bleeding. The lower lobe of the right lung was swollen and had the appearance of red tofu (bean curd) due to an intrapulmonary hematoma. A 4-cm tear was noted in both the right S6 and right S10 segments. The tears extended to a point near the pulmonary hilus. A right lower lobectomy was performed and was completed at 18:55, but the hemorrhagic shock persisted, with the systolic blood pressure remaining at 80 mmHg. At 19:40, the thorax was closed. At 20:00, angiography was started. Selective superior mesenteric arteriography revealed leakage of the contrast material from the A2 branch of the right hepatic artery (Fig. 4). At 20:19, embolization of the right hepatic artery distal to the bifurcation of the cystic artery was achieved. As a result, systolic blood pressure could be maintained at a higher level (100 mmHg), and bleeding from the thoracic drain decreased markedly. The total volume of the blood lost from the right thoracic cavity during the first 5 hours after the patient's arrival was 5,140 mL (2,000 mL lost via the thoracic drain before surgery, 2,240 mL lost during surgery, and 900 mL lost via the thoracic drain after surgery).

Postoperatively continuous positive pressure ventilation was applied to treat acute pulmonary edema (caused by the massive IV solution therapy and blood transfusion), pulmonary laceration, and multiple rib fractures on the right side. On hospital day 8, a tracheostomy was performed. On hospital day 11, the patient was weaned from the ventilator. On hospital day 21, an abscess was detected in the deeply lacerated area of the right lobe of the liver, but this complication was alleviated by percutaneous liver drainage. The patient was discharged on hospital day 57. On day 88 after injury, the liver drain was withdrawn. The patient resumed work 103 days after the injury.

DISCUSSION

In the USA, the Advanced Trauma Life Support (ATLS) guidelines for the diagnosis and treatment of high-energy trauma were published in 1997 [2]. In Japan, the Japan Advanced Trauma Evaluation and Care (JATEC), based on the ATLS guidelines, was made publicly available in 2002 [3]. Both the American and Japanese guidelines describe the appropriate methods of resuscitation and treatment, depending on the condition of each individual patient with high-energy trauma, and both attempt to unify the treatment methods.

The ATLS and JATEC guidelines provide direction on the insertion of thoracic drains and transfusion of the patient's own previously collected blood in the "Hemothorax" section of the chapter "Thoracic Trauma." According to these guidelines, an emergency open thoracotomy is indicated in the following three circumstances: (1) blood loss over 1,500 mL (according to ATLS) or 1,000 mL (according to JATEC) at

the time of insertion of a thoracic drain, (2) continued bleeding (over 200 mL/hour) for 2-4 hours, and (3) need for continuous blood transfusion [2, 3]. At our facility, we make it a rule to clamp the thoracic drain temporarily in hemothorax cases in which a blood volume exceeding 500 mL has been rapidly eliminated via the thoracic drain. If only a small amount of blood remains within the thoracic cavity on the chest radiograph obtained immediately after clamping of the thoracic drain, water seal drainage is performed again, and the volume of intrathoracic bleeding (assessed on the basis of blood output via the thoracic drain) is monitored. If a chest radiograph shows blood remaining in the thoracic cavity, and massive hemothorax is diagnosed, then we prepare for an emergency open thoracotomy while keeping the thoracic drain clamped. If the thoracic drain is clamped and positive pressure is retained within the thoracic cavity, it is possible to control blood loss to some extent because the pulmonary blood pressure is hypotensive. Furthermore, because clots of blood within the thoracic cavity cover the visceral side of the injured pleura, air leakage from the lungs during spontaneous breathing decreases. In patients in which ventilation is mechanically assisted, air leakage from the injured lung can be avoided if the injured side of the bronchus is obstructed with a Univent® tube [4, 5]. For the reasons mentioned above, we make it a rule to clamp the thoracic drain when dealing with patients with deep pulmonary lacerations. To date, we have not encountered a case in which cardiac arrest was caused by tension pneumothorax. In cases in which the thoracic drain was clamped, we occasionally lift the clamp and switch to water seal drainage to assess the situation within the thoracic cavity, as was done in the present case. However, we modified this procedure and presently make it a rule to continue clamping the thoracic drain until a thoracotomy is performed. If thoracic drainage is switched to water seal drainage or low pressure continuous aspiration, then a negative pressure within the thoracic cavity stimulates blood loss. The present patient developed shock immediately after thoracic drainage was switched to water seal drainage. As a result, he would have died from excessive blood loss before the start of a thoracotomy if the thoracic drain had not been clamped. The ATLS and JATEC guidelines contain few suggestions about the management of thoracic drainage in cases of severe thoracic trauma, and modifications in this respect thus appear to be warranted.

We classify the causes of hemothorax secondary to thoracic trauma into three types: (1) injury of the intercostal arteries and veins and thoracic vertebrae following chest wall injury, (2) deep pulmonary laceration, and (3) cardiovascular injury. The clinical findings and chest radiography findings are important for distinguishing these three types. If the vital signs are stable and the volume of blood loss via the thoracic drain stabilizes at some level, then bleeding from the chest wall or thoracic vertebrae is suggested. If parietal extrapleural hematoma is revealed on chest CT images, bleeding from the chest wall is quite certain. In cases in which signs of tension pneumothorax accompanied by mediastinal deviation are visible on the first chest radiograph, as well as in cases in which signs of hemothorax accompanied by air leakage are noted upon insertion of a thoracic drain, then deep pulmonary laceration is suggested. In the latter cases, the thoracic drain needs to be clamped, and an open thoracotomy must be initiated after IV solution therapy and blood transfusion have been prepared for application [4]. In cases in which the chest radiograph shows signs of hemothorax without accompanying pneumothorax, as well as in cases in which air leakage is absent but blood loss is seen upon the insertion of a thoracic drain, then cardiovascular injury is likely. In such cases, bleeding within the thoracic cavity cannot be controlled by clamping the thoracic drain, and we consider such cases to require an ultra-emergency open thoracotomy (immediate thoracotomy in the resuscitation room).

We consider an emergency open thoracotomy to be indicated in cases in which rapid bleeding (over 500 mL) is seen at the time of insertion of a thoracic drain. The same is true for cases in which blood loss within 2 hours after insertion of a thoracic drain exceeds 800 mL. In such cases, we make it a rule to perform open thoracotomy or exploratory video-assisted thoracoscopic surgery to the extent possible. From our viewpoint, patients showing intrathoracic bleeding should be treated by a thoracotomy and hemostasis in the acute stage after injury when the hemodynamic parameters have stabilized.

ATLS and JATEC provide guidelines for the diagnosis and treatment of high-energy trauma. According to these guidelines, a primary survey to evaluate the feasibility of resuscitation and treatment should be conducted in the sequence of ABCDE. If hemorrhagic shock is detected in segment C (circulation), then the guidelines recommend an initial IV solution therapy (1-2 L/30 minutes). A blood transfusion and immediate surgical hemostasis are recommended for patients, like ours, who do not respond to this therapy. In the present case, we performed an open thoracotomy prior to the other interventions, thus indicating judging that intrathoracic bleeding could have been the most life-threatening problem.

In conclusion, we emphasize that the initial diagnosis of this condition and the prompt resuscitation and treatment are key factors in determining whether or not we can save the lives of patients with multiple severe blunt trauma injuries. Surgeons specializing in trauma should therefore be familiar with the primary and secondary survey procedures described in the ATLS and JATEC guidelines, and they should diagnose and treat these conditions in parallel, with the goal of improving the survival of patients with high-energy trauma. It is thus desirable to prepare new guidelines pertaining to the management of thoracic drainage for patients with severe thoracic injuries.

REFERENCES

1) Inoue H, Shohtsu A, Ogawa J, Koide S, Kawada S. Endotracheal tube with movable blocker to prevent aspiration of intratracheal bleeding. Ann Thorac Surg 1984; 37: 497-499.
2) American College of Surgeons Committee on Trauma: Advanced Trauma Life Support (ATLS) for Doctors; Student Course Manual, 7th ed, Chicago: American College of Surgeons; 2004: 103-115.
3) The Japan Association for the Surgery of Trauma Committee

on Trauma Care and Education. Japan Advanced Trauma Evaluation and Care, 2nd ed, Japan: Herusu Shuppan 2004: 4-21, 43-60.
4) Nishiumi N, Maitani F, Tsurumi T, Kaga K, Iwasaki M, Inoue H. Blunt chest trauma with deep pulmonary laceration. Ann Thorac Surg 2001; 71: 314-318.
5) Nishiumi N, Maitani F, Yamada S, Kaga K, Iwasaki M, Inokuchi S, et al. Chest radiography assessment of tracheobronchial disruption associated with blunt chest trauma. J Trauma 2002; 53: 372-377.